Priority Capabilities Required to Enable Telepresence:
Sample Return to Orbiting Human Lab at Mars

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Context

- Assume mission is humans in Mars orbit: speed-of-light round trip to Earth is 6-42 minutes and will use high-bandwidth comm.
- Force-multiplier of many robots taking samples all the time, with decision-making up on orbit. Local humans take over when something interesting or bad happens.
- Topics open to debate (via trade studies):
  - Value of low-latency of operation of robots
  - Value of "graduate-student" sample preparation for instrument analysis
  - Value of being able to conduct "scientific method" at human lab: does that process suffer unduly from a 42 minute latency?
  - Value of short-stay human missions (30-60 days at Mars) versus long-stay missions
- Do not run survey grids or transects: assets too valuable for that.
- Need to get information quickly and turn it around and make a decision. How do you get the right decision made quickly?
- Flying (e.g., through Vallis Marinaris, or looking for methane sources) may require real-time control.
- Fast generation and validation of command sequences would be required – military does this routinely.
- Keeping humans away from sites where extant life may exist could be a compelling rationale for telepresence.
- Sample canister rendezvous, acquisition and return to the orbiting station needs to be demonstrated.

Findings for a Mars sample return to a crewed orbiting laboratory

- If a human mission to Mars orbit were carried out for national reasons, it would be an unfortunate mistake not to include low-latency control of robots on the surface.
- Most of the telerobotic technology exists for this mission, although its TRL needs to be advanced and validated for flight.
- Technology needed will be highly dependent on the nature of the mission and its timeline.
- On-orbit laboratory facilities, in terms of sample preparation and instruments, will be drivers.
- The ability for the on-orbit crew to control multiple robotic assets on the surface is imperative and/or to take over control of them from Earth operators when interesting or time-critical situations arise.
- Power and communications bandwidth are major drivers. Public outreach is a major driver for even-larger bandwidth.
- Taking a sample of biological significance may require very rapid encapsulation of the sample, which benefits from low-latency teleoperation.

Findings for a Mars sample return to a crewed orbiting laboratory (con't)

- A cis-lunar demonstration of this technology as a pre-requisite to a similar Mars mission would be valuable. This may also return samples of Aitken Basin and permanently shadowed regions that may not be otherwise acquired.
- A terrestrial demonstration of this technology would be an essential pre-requisite to a similar cis-lunar mission. These analog missions would assess the value of:
  - immersive displays,
  - controls, sensors, and feedback systems,
  - real-time re-projection from arbitrary vantage-points,
  - telepresence requirements, and
  - required operational protocols.
- Fast generation and validation of command sequences would be a change to existing NASA process flow.
- Geospatial posititioning infrastructure is highly enhancing.

Observations

- The understanding of some of these missions is too limited at presented to know whether low-latency teleoperation is required: biology missions, permanently-shadowed craters on moon, etc.

- Crew time is a scarce resource and telerobotics can be used to perform habitat maintenance: a method must be found to free enough crew time to do the priority mission.
[Robonaut-2 can help prove this technology at ISS.]

- Many aspects of these alternative missions seem unbounded: many parameters are poorly constrained by our uncertain state of knowledge.

Next Steps

- An operations feasibility assessment at analog site should be conducted comparing solely human *in-situ,* on-orbit low-latency telerobotics, and long-latency telerobotics. This could also evaluate display and control technologies, return vs. bandwidth, etc.

- This almost certainly will be an international endeavor and interoperability standards need to be defined and agreed.